California Environmental Protection Agency
Environmental Technology Certification Program

Evaluation of the AquaShield™ Filtration System (Model SD-100, Series 576)

January 2000

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A. Introduction

1. Certification Program

Effective August 19, 1996, Section 71011 and 71031 of the California Public Resources Code (PRC) directs all California Environmental Protection Agency (Cal/EPA) Boards and Departments, including the State Water Resources Control Board (SWRCB), to adopt a voluntary statewide program to certify the performance of environmental technologies. The SWRCB adopted the Implementation Policy for Environmental Technology Certification Program at a September 1997 Board meeting with Resolution 97-078-CWP. This Policy allows proponents of a technology to request that the SWRCB staff conduct an independent third-party verification of performance claims focusing on the water quality benefits of the technology.

In accordance with this Policy, SWRCB staff has evaluated the AquaShield™ Filtration System (Model SD-100, Series 576). This report was prepared to show the results of this evaluation. The evaluation is based on a detailed review of validation materials submitted by the manufacturer and original data generated by an independent laboratory, whose findings were considered reliable by SWRCB staff. This Certification is strictly a performance certification and does not imply that the technology has been permitted for any application. The information contained in this report, may however, be used by a regulatory authority as background and performance information that may be needed to achieve an environmental permit. The permitting authority is maintained by the applicable environmental permitting agency.

2. Overview of Regulatory Process for Technology Sector

Non point sources are a major contributor to water pollution. Reduction of these non point source pollutants combined with treatment or removal of pollutants is an important step in maintaining the water quality objectives in California.

Under the Clean Water Act, discharges from a municipal separate storm sewer system (MS4) which serve a population of 100,000 or more must be in compliance with an NPDES permit. These permits require that the owner/operator reduce storm water pollution to the maximum extent practicable.

Due to the episodic nature of storm water flows and the high variability of storm water quality, it was not practicable to develop numeric limits for storm water discharges. These same reasons also make it very difficult for a municipality to provide treatment for storm water discharges, in a fashion similar to wastewater flows. Therefore, best management practices (BMPs) have been utilized, to the maximum extent practicable, to achieve pollutant reduction in storm water discharges. These BMPs include public education and outreach, preventative maintenance and the use of treatment devices such as oil/water separators.

3. Certification Limitations

The SWRCB makes no express or implied warranties as to the performance of the manufacturer's product or equipment. SWRCB staff has not conducted any bench or field tests to confirm the manufacturer's performance data. Nor does the SWRCB warrant that the manufacturer's product or equipment is free from any defects in workmanship or matters caused by negligence, misuse, accident, or other causes.

SWRCB staff believes, however, that the manufacturer's product or equipment can achieve performance levels set out in this Certification. Our determination is based on a review of the data submitted by the manufacturer and other information, and is based on the use of the product in accordance with the manufacture's specifications.

This certification does not relieve the manufacturer of any permits required by local or state authorities governing storm water pollution.

By accepting this Certification, the manufacturer assumes, for the duration of the Certification, responsibility for maintaining the quality of the materials and equipment at a level equal or better than was provided to obtain this Certification and agrees to be subject to quality monitoring by Cal/EPA.

B. Performance Claim

The AquaShield™ Filtration System (Model SD-100, Series 576), installed and maintained as described in the "Design, Operation & Maintenance Technical Manual", removes 92% of oil and diesel fuel in water, with a 95% confidence interval, when the influent concentrations are between 1,000 to 2,000 milligrams per liter (mg/l). This system does not leach more than 30.4 mg/l of oil and diesel back into the clean water.

C. Materials Available For Evaluations

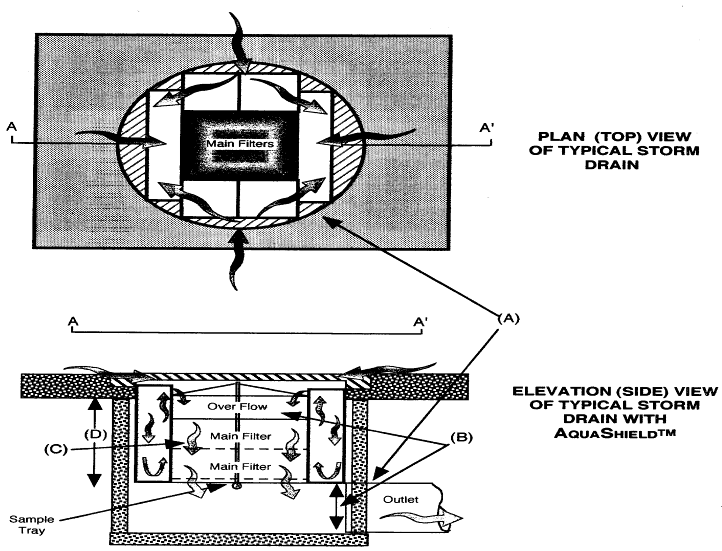
The following materials were used as part of our evaluation of the AquaShield™ Filtration System performance claim:

1. California ETC – Application for Certification AquaShield™ Filtration System, May 21, 1998.
2. AquaShield Filtration Systems, Design, Operation & Maintenance Technical Manual, July 1998.
3. Filtersorb Material Safety Data Sheet, Cellutech
4. Test Results – No. 4, AquaShield™ Filtration System, Letter to Bryan Brock (SWRCB), May 28, 1998.
5. Environmental Technology Certification (ETC) AquaShield™ Filtration System, Performance Claim Investigation Results, Letter to Bryan Brock (SWRCB), August 23, 1999.
6. Remedial Solutions Video, Aqua Shield System, Final Analysis and testing, by Analytical Industrial Research Laboratories, June 18, 1999.
7. AquaShield™ Filtration System Technology, Qualification Statement, Remedial Solutions, Inc., January 2, 1998

D. Technology Description

The AquaShield™ Filtration System (Model SD-100, Series 576) is a storm drain insert, containing an oil absorbent/water repellent material, which partially separates oil from water and stores the contaminant in the filter media. This technology is also designed to create an even distribution of contaminated water runoff over the filter media to optimize absorption.

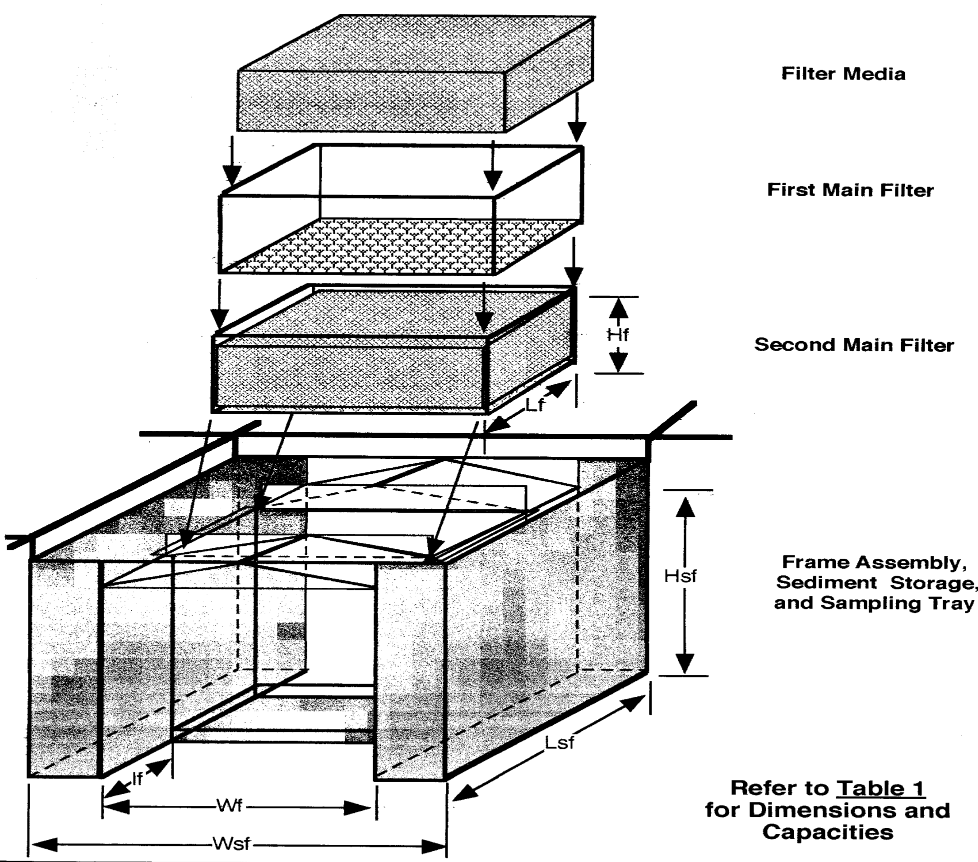
The AquaShield™ is constructed of stainless steel containing 20-30% pre-consumer recycled material. The internal framework is heavy gauge steel angle iron material and designed to rigidly support, protect, and maintain proper alignment of all mating surfaces.



AquaShield™ Filtration System Patent Pending		Surface Drain (SD-100) Model PROCESS FLOW
Remedial Solutions, Inc. One Northgate Park, Suite 406 Chattanooga, Tennessee 37415 (423) 870-8888 www.remedialsolutions.com	Notes: (A) Surface drain opening and outlet size are determined by drainage system engineer/designer (B) Area of sediment overflow opening equals discharge pipe opening (C) Oil removal capacities are based on 2 main filter stages (D) Minimum depth is 24-in. for standard 3-stage unit	EX15:25 July 1, 1998 Figure 3

The AquaShield™ is designed with a small sediment basin on the perimeter of the filter media area, to catch debris prior to filter media contact. The amount of debris storage is dependent upon the size of the AquaShield™. The AquaShield™ also has a spillway bypass to minimize the affects of clogging.

This spillway is typically designed to equal or exceed the storm-drain pipe capacity. Frequent monitoring and maintenance is necessary for proper performance of the technology. Maintenance should be in accordance with the Design, Operations, and Maintenance Technical Manual dated July 1998.



AquaShield™ Filtration System Patent Pending

Surface Drain (SD-100) Model Exploded View

Remedial Solutions, Inc.
One Northgate Park, Suite 406
Chattanooga, Tennessee 37415
(423) 870-8888
www.remedialsolutions.com

Notes:
(A) Refer to Figure 4 for Process Flow
(B) All materials are stainless steel or hot dipped galvanized steel
(C) Oil removal capacities are based on 2 main filter stages
(D) Minimum depth is 24-in. for standard 3-stage unit

EX15:25

July 1, 1998

Figure 2

The filter media is made from recycled cellulose fibers from the paper making industry. The cellulose fiber absorbs liquids into the fibers through capillary action and has been treated with non-crystalline silica to repel water and water based liquids. The filter media is packed loosely into a nylon mesh bag to maximize the contaminant contact area, and minimize the replacement effort for spent media. The AquaShield™ manufacturer states the total absorbent capacity of the filter media is 4 gallons per cubic foot (gal/ft^3); however, this parameter was not tested as part of this Certification.

The unused filter media product is non-hazardous as defined by CFR 1910.120 or RCRA 40 CFR Part 261 according to the manufacturer's Material Safety Data Sheet. This product has not undergone the appropriate testing and has not fulfilled the requirement to be deemed non-hazardous under California hazardous waste laws. Spent filter media, if being disposed of, as solid waste should be characterized to ensure that it does not meet the criteria for hazardous waste in California.

E. Testing & Evaluation

1. Test Procedures

The testing protocol, as described below, was developed to simulate high concentration stormwater runoff over relatively small areas. Simulated flows are intended to be consistent with automobile parts and accessories parking lots, gas stations, and fast food drive-through areas. The protocol was not developed to be consistent with normal street or highway runoff.

The testing procedures involved contaminating water with diesel fuel and motor oil and measuring the removal of these contaminants after flowing through the AquaShield™. Testing for this Certification was completed in a controlled environment and was not subject to variables associated with field-testing.

Seven (7) separate tests were conducted for this investigation to statistically substantiate the performance claim. Each test included taking individual grab samples as well as composite samples of the treated effluent water for analysis to determine the concentrations of oil and diesel content. Total mass removed and mass balance calculations were used to verify the laboratory analysis data.

Tables that summarize this data are provided in this report. The testing procedures are summarized below.

1. Weigh each filter (resin) dry in kilograms (KG)
2. Wash each filter with clean tap water
3. Re-weigh the wet filters in KG
4. Weigh the mixture of 4 gallons of diesel and 1 gallon of oil and the container; determine the specific gravity of the mixture
5. Begin the flow of water and the oil/diesel mixture into the AquaShield™
6. Take sample of the influent and analyze for concentrations of oil and grease in mg/l.
7. Obtain instantaneous effluent samples at 45 minute intervals and start rinsing with clean water
8. Obtain instantaneous effluent samples at 45 minute intervals for concentrations of oil and grease in mg/l
9. Secure composite sample from ISCO sampler and analyze for concentrations of oil and grease in mg/l
10. Determine the total amount of water used during this phase of the test
11. Conduct the final weighing of the filters in KG
12. Summarize the test data and complete the necessary calculations to evaluate the performance of the AquaShield™.
13. Begin process again starting with step 5, however this time use clean tap water, not water contaminated with oil and grease.

2. Data Quality Assurance/Control

Several Quality Assurance measures were taken to control the quality of the data obtained during the testing of the filtering equipment.   Analytical Industrial Research Laboratory provided a Quality Assurance/Quality Control Plan (Section 9) of their product submittal. In summary, the following QA/QC measures were followed

1. EPA Test Methods were used where applicable

2. Chain-of-custody forms were used to track influent/effluent samples
3. Sample collection and preservation methods were used to ensure integrity of the sample
4. A certified analytical laboratory was used for all analysis. Analytical Industrial Research Laboratories is certified (Certificate No. 340) by the North Carolina Department of Environment and Natural Resources to perform wastewater analysis to include Petroleum Hydrocarbons RBCA Methods Extractables (EPH) and Volatiles (VPH).
5. Composite, grab and instantaneous sampling were performed to reduce uncertainty in sampling methods.
6. Decontamination procedures were used on all equipment to minimize cross-contamination issues.

3. Equipment

The following is a brief description of the equipment used during this investigation and the physical set up of the test site. Additionally, All equipment was thoroughly cleaned between each test to guard against cross contamination of materials.

A. A typical AquaShield™ Filtration System, Model SD-100, Series 576, was installed in a wooden frame elevated approximately ten feet above the ground for support during this series of tests. A catch basin was constructed beneath the AquaShield™ Filtration System to capture all of the effluent water before discharging into the sanitary sewer system or being captured for re-use in a 500 gallon polyethylene tank.
B. An ISCO sampler was used to obtain composite samples of the effluent water.
C. A positive displacement rotary lobe tubular pump was used to introduce the oil and diesel mixture into the water supply entering the AquaShield™.

D. An Ohaus scale, which measures in milligrams (mg) and kilograms (KG), was used to determine the before and after weights of the filters and other containers used during each of the tests.

E. Standard stainless steel laboratory utensils, tools and glass containers were used to minimize any possibility of transfer or loss of any captured contaminants from the filters to another substance or article that could attract the petroleum hydrocarbons.

F. A standard flow meter, measuring in milliliters (ml) and gallons, was used to monitor the amount of liquid entering the AquaShield™ Filtration System throughout the tests.

G. Water flow was controlled with a fixed orifice flow control inserted by AIRL into the piping used to route the liquids to the proper equipment.

H. The temperature and pH of the water were monitored with digital meters to the nearest tenth.

I. A positive displacement rotary pump was used to transfer the liquids from their containers to the AquaShield™ and from the storage tank back to the contaminant mixture container.

J. A 500-gallon agricultural grade polyethylene above ground storage tank was used to capture the effluent water for the final three (3) tests. This tank was positioned directly below catch basin and between the wooden scaffold holding the Series 576 AquaShield™

K. A gravimetric analysis was used by Analytical Industrial Research Laboratories, Inc. (AIRL) to determine the concentration of oil and diesel mixture in the influent and the effluent water samples and reported in milligrams per liter (mg/l). United States Environmental Protection Agency

(EPA) method 413.1 was used in accordance with EPA 600/479-02 (revised 1992) procedure manual methods for chemical analysis of water and wastewater.

4. Contaminant Mixture

Normal tap water was the base liquid for the contaminant mixture introduced into the AquaShield™ Filtration System Series 576. A mixture of 1 gallon of 10W30 motor oil and 4 gallons of diesel fuel was placed in a dry weighed container. The specific gravity of the oil and diesel mixture was between 0.83 grams per milliliter (g/ml) and 0.86 g/ml.

The oil and diesel mixture was pumped into the tap water at a flow rate ranging from 100 milliliters per minute (ml/min.) to 45 ml/min. depending on the specific test being conducted at that time. The contaminant mixture was then pumped at a constant rate of 10 gallons per minute (gpm) into the AquaShield™. No additives or emulsifiers were used in the contaminant mixture for these tests.

During the lasts three (3) tests, the 500-gallon storage tank captured all of the water all through the tests. Therefore, any residual oil/diesel that was not captured by the filters was re-introduced into the AquaShield™. This circulation of 500 gallons of water continued until the container with the five (5) gallons of oil/diesel was empty.

The water and oil/diesel contaminant was introduced to the AquaShield™ using 2-inch diameter schedule 40 PVC piping that allowed the combined fluids to travel evenly into the treatment system from all sides. The flow rate of the contaminant was maintained at 10 gpm with a fixed orifice flow control insert. The temperature of the contaminant mixture varied according to the outside ambient air temperature (60° to 80°F) and the pH ranged between 6.5 and 7.5 throughout the tests.

The chemical concentrations of oil/diesel in the influent ranged from a high of 2,192 mg/l to a low of 1,022 mg/l, with an average of 1,477 mg/l. The influent and effluent concentration and the percent removal for each of the laboratory tests were calculated.

The total mass (weight) of oil/diesel introduced into the AquaShield™ Filtration System ranged from 16.89 kilograms (KG) to 15.82 KG, with an average of 16.29 kg.

5. Sample Collection

Three measuring techniques were used to provide a database to confirm the contaminant removal performance of the AquaShield™. The instantaneous or individual grab sample represents the concentration of oil and diesel contaminant (as oil and grease) measured at any one specific moment at a constant flow rate. Continuous or composite samples characterize the concentration of the contaminant over the length of the test. Mass analysis was also used to determine the weight of oil retained on the filter versus the weight of oil passing through the system.

The results from these differing techniques can be compared to one another to achieve a greater confidence in any one of the testing outcomes. Descriptions of these analytical methods are provided.

6. Instantaneous Grab Samples

Instantaneous samples of the effluent were taken for each of the seven (7) tests by collecting water from the catch basin secured under the AquaShield™ Series 576. Four (4) instantaneous effluent samples were taken for the first four (4) tests and three (3) instantaneous samples were obtained for the last three (3) tests.

The sample containers were pint amber glass jars having a hydrochloric acid (HCL) preservative with a pH of <2. After securing the proper amount of water, the sample containers were immediately taken inside the laboratory facility for analysis.

The samples were immediately taken to the laboratory, where they were analyzed for hydrocarbon content recorded in milligrams per liter.

After the data was collected for the seven tests, the percent removal for each of the samples was calculated by dividing the concentration of the effluent sample by the known influent concentration and subtracting that number from 100 percent. The four samples for each test were then averaged to obtain a mean percentage removal for that individual test. A synopsis of this information is shown in the table below.

Grab Sample Information

		Grab Samples				Grab Sample Removal Percentage				Removal
Test (number)	Influent (mg/l)	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Sample 4 (mg/l)	Sample 1 (%)	Sample 2 (%)	Sample 3 (%)	Sample 4 (%)	Average (%)
2	2192	242.90	19.70	25.60	7.20	0.89	0.99	0.99	1.00	0.97
3	1420	50.50	22.50	21.70	20.50	0.96	0.98	0.98	0.99	0.98
4	1420	30.40	10.10	15.10	10.10	0.98	0.99	0.99	0.99	0.99
5	1420	55.00	24.20	30.20	15.10	0.96	0.98	0.98	0.99	0.98
6	1420	211.80	57.90	48.40		0.85	0.96	0.97		0.93
7	1446	181.50	203.50	36.60		0.87	0.86	0.97		0.90
8	1022	12.80	91.60	132.50		0.99	0.91	0.87		0.92

7. Composite Samples

An ISCO sampler collected the necessary volume of effluent water throughout this phase of the test for the composite samples. The ISCO sampler transferred the fluids directly into the laboratory prepared containers and assures the preservative in the sample containers is maintained and the proper volume of liquid is obtained for analysis.

The laboratory technician capped each container when filled and prepared the vials for immediate analysis using the same EPA testing method as described for the grab samples.

After all of the data was collected for the seven tests, the percent removal for each of the samples was calculated by dividing the concentration of the effluent sample by the known influent concentration and subtracting that number from 100 percent. A synopsis of this information is shown in the table below
.

Composite Sample Information

	Composite Samples		
Test (number)	Influent (mg/l)	Effluent (mg/l)	Removal (%)
2	2192	42	0.98
3	1420	26.2	0.98
4	1420	15.3	0.99
5	1420	28.2	0.98
6	1420	115.4	0.92
7	1446	413.7	0.71
8	1022	63.3	0.94

8. Mass Analysis

The mass of oil and diesel removed by the filter media can be calculated from influent and effluent contaminant concentrations and the total flow. The total weight of oil/diesel added (W_{to}) equals the weight of the oil/diesel and the container, minus the weight of the container. The weight of oil/diesel not captured (W_{ol}) during the test can be calculated from the effluent contaminant concentration (C_E) and the total volume of liquid used in the test. The formula for calculating the weight of oil/diesel not captured is:

$$\boxed{\text{Total Volume} \times C_E / 1\text{x}10^6}$$

The mass of the filter was not directly used, because of additional contaminant retention and/or water retention that occurred. The total weight of oil/diesel captured by the filters (W_{or}) equals the total oil/diesel added (W_{to}), minus the sum of the oil/diesel not treated during the test phase (W_{ol}). The percent recovery is expressed by dividing the total W_{or} by W_{to}. The table below illustrates the information used to determine the percent recovery, on a mass basis, for each test.

Mass Analysis Data

Test	W_{to} (kg)	Flow (Gal)	Ce (mg/l)	W_{ol} (kg)	%
2	15.82	1850	42	0.29	98.14
3	16.52	3000	26.2	0.30	98.20
4	16.04	3000	15.3	0.17	98.92
5	16.89	3050	28.2	0.33	98.07
6	16.53	3050	115.4	1.33	91.94
7	15.94	2900	413.7	4.54	71.51
8	16.32	4050	63.6	0.98	94.03

9. Leachate Samples

In order to evaluate the ability of the AquaShield™ Filtration System, Series 576 to retain the oil/diesel captured in the filters, a leachate test was conducted on the contaminated filters. The procedures for tests #2 through #5 consisted of simply rinsing the filters in the AquaShield™ with clean tap water for an extended period of time and obtaining individual grab samples as well as a composite sample from each test.

After re-weighing the filters and replacing them in the AquaShield™, clean tap water was introduced again during the first four (4) tests to simulate the continuation of a storm event. Instantaneous or grab samples, as well as composite samples were taken from the rinse water (effluent only) to determine a quantity of oil and diesel that could be released from the system following the capture of the contaminants.

The procedures were the same for tests #6, #7 and #8 except that the 500 gallon tank was used to hold all of the water for re-circulation to the AquaShield™ Filtration System, Series 576 as previously described. Consequently, the influent rinse water was not free of oil and diesel; therefore, representing a more difficult performance scenario. This scenario was considered, because it would only hinder the technology performance yielding lower results. As before, instantaneous or grab samples, as well as composite samples were taken.

The weight of oil and diesel used during the test was determined by weighing the empty oil container as well as the filters after stopping the flow of the contaminated water. The before test (wet) and after test weight of each filter was measured in kilograms (KG) and then compared in order to evaluate the total mass gained during the testing.

Rinse Data

Test	Total Flow Gallons	Grab 1 mg/l	Grab 2 mg/l	Grab 3 mg/l	Grab 4 mg/l	Ave. Grab mg/l	Composite mg/l
2	1900	5.20	8.70	6.70	2.00	5.65	8.40
3	3000	8.60	6.50	5.50	4.50	6.28	6.10
4	3000	10.20	7.90	9.50	4.30	7.98	8.30
5	3000	15.20	10.60	14.60	12.10	13.13	12.80
6	3000	25.60	11.70	10.10	12.80	15.05	10.20
7	3000	55.50	59.20	28.70	44.50	46.98	49.20
8	5100	23.30	24.70	32.80	26.90	26.93	22.80

F. Conclusions

Based on the results of the testing conducted, the AquaShield™ Filtration System Model SD-100, Series 576 achieved a removal rate of 92% when applying a confidence interval (CI) of 95%. This removal rate was verified for a given influent flow of 10 gal/min with a range of oil/diesel contaminant concentration of 1022 m/l to 2192 mg/l. The test results showed that percentage removal rates for the seven tests, using the mean value for grab samples taken for a given test, ranged from 90% to 99%, with a mean of 95% and standard deviation of 3%.

Composite and grab sample data could not be combined statistically because they measure the same information. Grab sample data was used to validate the performance claim because it appeared to provide better representation of the performance over the seven tests. Six of the tests showed consistent composite sample data; however, composite sample data for test number seven seemed to be inconsistent. SWRCB staff does not believe that this aberration is significant because good correlation between grab and composite samples in the other tests was realized. Therefore, composite sampling data shows a close data correlation between the two types of sampling techniques giving us confidence in the data quality.

The rinse data obtained from testing performed on the contaminated filters showed that contaminant concentration from mean grab samples varied from 5.65 mg/l to 46.98 mg/l. The average contaminant concentration was 17.43 mg/l with a standard deviation of 13.75 mg/l. The 95% confidence interval was C.I. = 17.42 $\pm$ 11.00 with an upper limit of 28.43 mg/l.

Composite sample results were consistent with grab sample results with a range of 6.10 mg/l to 49.20 mg/l, a mean of 16.83 mg/l and standard deviation of 14.16 mg/l. The 95% confidence interval for the composite samples was C.I. = 16.83 $\pm$ 11.33 with an upper limit of 28.15 mg/l. Thus the performance claim of filter leaching of no greater than 30.4 mg/l was validated by testing results.
It should be noted that influent rinse water contaminant concentrations were not measured and therefore no relative comparison can be made between influent and effluent concentrations.

For examples and references of statistical analysis performed for this evaluation see Appendix A.

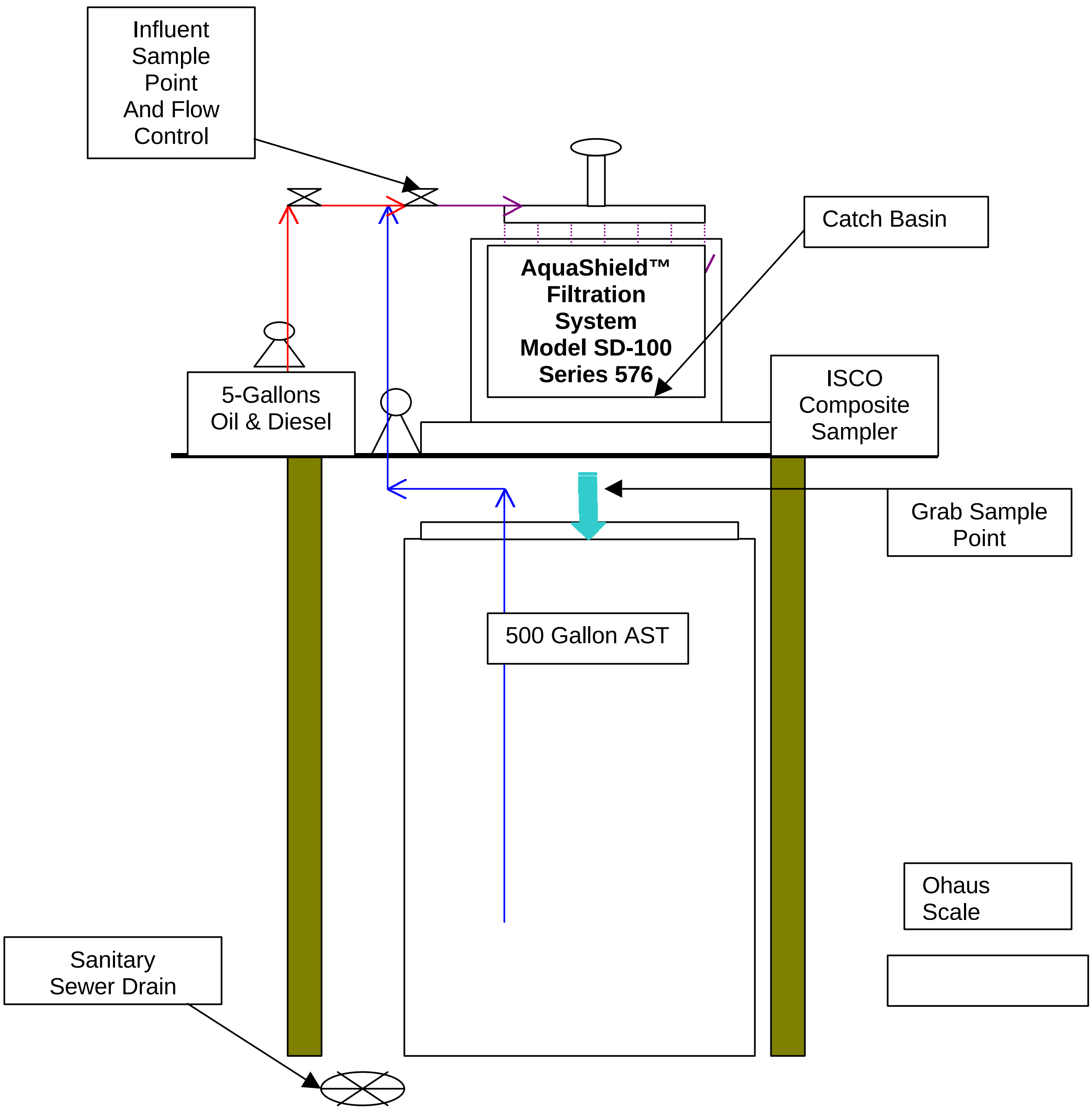
G. Recommendations

The results of testing indicate that the manufacturer's performance claim has been validated for specified operating parameters stated in this document. SWRCB staff recommends that the AquaShield^{TM} Filtration System (Model SD-100, Series 576) be certified under CAL-EPA's Calcert program.

PROCESS FLOW DIAGRAM

AquaShield™ Filtration System

California - Environmental Technology Certification



Appendix A
Sample Statistical Calculations

The following equations and calculations were used for statistical analysis of Aqua-Shield Filter test data:

From <u>*Probability and Statistics*</u>*, Lindgren, McElrath and Berry, 1978*:

a. Mean: $\mathbf{X = (\sum X_i) / n}$

where X is mean value,
X_I is value for test data
n is number of test data

b. Standard Deviation: $\mathbf{S = \sqrt{(1 / n) * \sum (X_i - X)^2}}$

where S is standard deviation value
n is number of test data
X is mean value,
X_I is value for test data

c. Confidence Interval: $\mathbf{C.I. = X \pm t_{.95} * S / \sqrt{(n - 1)}}$

where C.I. is lower & upper value for which there is a 95% probability that data in a specified set (specified by X, S and n) will fall between the upper and lower value.
S is standard deviation value
n is number of test data
X is mean value,
$t_{.95}$ is the t-tail value for a 2-tailed normal distribution
(in this case $t_{.95} = 1.96$)

1. Removal Rate using Mean of Grab Sample Values:

Removal Percentage = $1 - (C_E / C_I)$,

where C_E = Effluent Contaminant Concentration
C_I = Influent Contaminant Concentration

$X_2 = 1 - (73.85 \text{ mg/l} / 2192 \text{ mg/l}) = .97$,
$X_3 = 1 - (28.80 \text{ mg/l} / 1420 \text{ mg/l}) = .98$,
$X_4 = 1 - (16.43 \text{ mg/l} / 1420 \text{ mg/l}) = .99$,
$X_5 = 1 - (31.13 \text{ mg/l} / 1420 \text{ mg/l}) = .98$,
$X_6 = 1 - (106.03 \text{ mg/l} / 1420 \text{ mg/l}) = .93$,

$\mathbf{X = (\sum X_i) / n = .95}$

$\mathbf{S = \sqrt{(1 / n) * \sum (X_i - X)^2} = .033}$

X_7 = 1 – (140.53 mg/l / 1446 mg/l) = .90,
X_8 = 1 – (78.97 mg/l / 1022 mg/l) = .92

C.I. = X ± $t_{.95}$ * S/ $\sqrt{(n-1)}$ X = .95, S = .03, n = 7, $t_{.95}$ = 1.96

C.I. = .95 ± .026 (or C.I. (lower) = .98, C.I. (upper) = .92)

For Grab Sample data, mean removal rate is .95 with a confidence interval of .95 ± .026 (lower limit of .92).

2. Composite Sample Removal Rates

Using the composite sample effluent concentrations, the following removal rates were calculated:

Removal Percentage = 1 – (C_E / C_I) ,

where C_E = Effluent Contaminant Concentration
C_I = Influent Contaminant Concentration

Test 2 :	1 – 42 mg/l / 2192 mg/l = .98
Test 3:	1 – 26.2 mg/l / 1420 mg/l = .98
Test 4:	1 – 15.3 mg/l / 1420 mg/l = .99
Test 5:	1 – 28.2 mg/l / 1420 mg/l = .98
Test 6:	1 – 115.4 mg/l / 1420 mg/l = .92
Test 7:	1 – 413.7 mg/l / 1446 mg/l = .71
Test 8:	1 – 63.3 mg/l / 1022 mg/l = .94

X = ($\sum X_i$) / n = .93

S = $\sqrt{(1/7) * \sum (X_i - .93)^2}$ =.092

C.I. = X ± $t_{.95}$ * S/ $\sqrt{(n-1)}$ X = .93, S = .092, n = 7, $t_{.95}$ = 1.96

C.I. = .93 + 1.96 (.092 / $\sqrt{(7-1)}$)

C.I. = .93 ± .062, Upper limit .99, Lower limit .87

Thus composite sample mean removal rate does not support performance claim. However if the result from Test 7 is "thrown-out" (since it is inconsistent with the removal rate data) and the number of samples is reduced to 6. The mean removal rate is

X = ($\sum X_i$) / 6 = .96

$S = \sqrt{(1/6) * \sum (X_i - .96)^2} = .026$

C.I. $= X \pm t_{.95} * S/\sqrt{(n-1)}$ $X = .96$, $S = .026$, $n = 6$, $t_{.95} = 1.96$

C.I. $= .96 \pm 1.96\ (\ .026\ /\ \sqrt{(6-1)}\ )$

C.I. $= .96 \pm .023$ upper limit = .98, lower limit = .94

Thus if the result for test no. 7 were "thrown-out" the remaining removal rate data would support the performance claim. Based on the removal rate data for both the grab and composite samples this is a reasonable assumption.

3. Rinsewater Data Statistical Calculations

Using the mean grab sample results

$X = (\sum X_i) / 7 = 17.43$

$S = \sqrt{(1/7) * \sum (X_i - 17.43)^2} = 13.75$

C.I. $= X \pm t_{.95} * S/\sqrt{(n-1)}$ $X = 17.43$, $S = 13.75$, $n = 7$, $t_{.95} = 1.96$

C.I. $= 17.43 + 1.96\ (\ 13.75\ /\ \sqrt{(7-1)}\ )$

C.I. $= 17.43 \pm 11.00$, Upper limit 28.43, Lower limit 6.43

Using the composite sample results

$X = (\sum X_i) / 7 = 16.83$

$S = \sqrt{(1/7) * \sum (X_i - 16.83)^2} = 14.16$

C.I. $= X \pm t_{.95} * S/\sqrt{(n-1)}$ $X = 16.83$, $S = 14.16$, $n = 7$, $t_{.95} = 1.96$

C.I. $= 16.83 + 1.96\ (\ 14.16\ /\ \sqrt{(7-1)}\ )$

C.I. $= 16.83 \pm 11.33$, Upper limit 28.15, Lower limit 5.50